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ON THE VARIABILITY OF STARS

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In several IBVS contributions, my students, colleagues, and I investigated the Hipparcos photometry (ESA 1997) of stars in the Bright Star Catalogue 5th edition (Hoffleit & Warren 1991) and the Supplement of the 4th edition (Hoffleit et al. 1983). We found the mean amplitude as a function of spectral type. We identified the most variable stars and noted some which should be considered by observers for further study. We discussed the presence of unusually quiescent stars and when space permitted gave lists. By excluding the values from stars whose spurious variability is due to binarity as noted by the Celestia program (ESA 1998), we attempted to give values for single stars. Then by removing values due to stars whose photometric amplitudes based on three years of data were atypically large compared to the mean for the spectral type, we attempted to provide average values for most typical stars. But due to the way they were selected, these average values are thus likely to be smaller than one would find for a randomly selected star of a particular spectral type, especially in the instability strip or for types where a large percentage were primary stars of binary systems.

Figure 1 plots luminosity class vs. Harvard spectral type. It displays mean amplitudes multiplied by 1000, combines the Ia and Ib supergiants, and does not show intermediate type values. To help visualize the least variable stars, I used larger font sizes for smaller amplitudes and for those amplitudes less than $0\overset{m}{.}023$ I used bold face to aid visualization. The data are from: Adelman & Albayrak (1997) for A0–A7 I supergiants, Adelman, Cay, Cay, & Kocer (2000) for the F supergiants and the A II stars, Adelman, Yüce, & Engin (2000) for O and B supergiants, Adelman, Mayer, & Rosidivito (2000) for O9–B5 III–V stars, Adelman, Gentry, & Sudiana (2000) for B6–B9 III–V stars, Adelman, Flores, & Patel (2000) for A0–A2 III–V stars, Adelman (2000c) for A3–F0 III–V stars, Adelman, Coursey, & Harris (2000) for F1–F9 III–V stars, Adelman, Davis, & Lee (2000) for G0–G9 stars, Adelman (2000a) for early K stars, and Adelman (2000b) for K5–M stars. As Hipparcos only obtained stellar photometry for three years, stars with much longer periods are unlikely to have been found to be variable unless their amplitudes are very large. Further the means certainly include some small amplitude variables which remain to be discovered. The average values are based on at least three, but in some cases over 100 values. Almost all of these stars are members of Population I.

The smallest amplitudes ($0\overset{m}{.}015$ to $0\overset{m}{.}022$) are between spectral types A0 and K0. The most pronounced region of least variability is found among the A stars. It is centered at spectral types A0 IV and A0 V, runs to A4 III and A4 IV and then to A6 IV. The classical instability strip occurs in the late A and early F stars. Then there is another less pronounced region of least variability which is centered at F2 III and proceeds to F6 IV and F6 V, then to F9IV and to K0 II. It includes the G6 II stars which have the smallest mean amplitude of $0\overset{m}{.}015$. Many stars with convective envelopes are likely to be long term variables with solar-type dynamos and periods greater than 3 years. In the late B stars, there is a region of not quite minimal variability from B7 III to B9 IV. Near B2 and B3 among the main sequence band stars one can see an increase in amplitude where the β Cep and similar types stars are found.

	O9	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	F0	F1	F2	F3	F4	F5	F6	F7
I	49	49	49	49	58	58	58	58	58	58	58	52	52	52	52	52	36	36	36	36	36	41	41	41	41	41	41	41	41
II	29	29	29	29	28	28	28	28	28	28	28	36	36	36	36	36	36	29	29	29	29	25	25	25	25	25	25	25	25
III		27	42	55	36	33	32	28	25	26	26	25	25	**22**	23	**20**	**22**		25	**19**	28	25	23	**21**	**22**	28	**21**	25	40
IV		25	33	32	28	30	30	30	30	28	24	**20**	**22**	**22**	**22**	**22**	**22**	**20**	24	23	26	23	28	23	24	29	25	**22**	26
V	42	35	35	32	33	38	32	32	28	25	25	**22**	**22**	23	26	27	24	26	29	28	29	28	26	26	24	23	**22**	**21**	27

	F7	F8	F9	G0	G1	G2	G3	G4	G5	G6	G7	G8	G9	K0	K1	K2	K3	K4	K5	K6	K7	M0	M1	M2	M3	M4	M5	M6	M7
I	41	41	41	23		23	**20**		**22**			30		35	35	35	40	57	60										
II	25	25	25						23	**15**		23		**19**	24	26	27	43	33				83		146	302	493		
III	40	**22**		23		**22**	28	**20**	25	24	23	24	**22**	25	25	27	26	29	35	34	34	43	62	83	126	193	328	478	3120
IV	26	25	**20**	32	**20**	23	**20**		28	**20**		30	25	25	28														
V	27	26	25	25	24	26	24	28	29	**22**	30	25	30	34	44	37	31	40	247										

spectral type

Figure 1. The amplitude of variability as a function of Harvard spectral type and luminosity class. The values are 1000 times the amplitudes in magnitudes

Eyer & Grenon (1997) investigated photometric variability in the HR diagram among all the stars investigated by Hipparcos. For the most part our general conclusions about minimal variability are similar, but some differences are due to the use of different sources for the spectral types. Those stars with composite spectra complicate the analysis. The most important difference is that they believe that the G8 II to G8 V stars are the most stable, but I prefer instead the A stars noted above. This may reflect my experience in studying the magnetic CP stars and being able to more readably exclude them from the sample.

These studies despite their problems still provide useful guidance for selecting appropriate comparison stars for differential photometry. But it is still desirable to investigate the published data, especially the photometry and radial velocities, before using a star as a comparison and even more so as a standard.

To extend such studies, it would be desirable to have a greater consistency of the spectral types. The Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars (see, e.g., Houk & Swift 1999) when completed will admirably serve this purpose. Further a consistent method of eliminating significant photometric contributions from stellar companions is needed such as the use of multi-filter photometry (see Moro & Munari 2000 for a census of systems) of which the Strömvil system (Straizys, Crawford & Philip 1996) is one of many possible choices and/or spectrophotometry. Finally one has to extend the time span of the observations to at least order 10 years which is difficult using a space mission alone, but might be possible with a network of ground-based telescopes obtaining photometry consistent with that from one or more space missions.

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